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LOWER RESPIRATORY SYMPTOMS IN CHILDREN EXPOSED TO NITROGEN DIOXIDE FROM UNVENTED COMBUSTION SOURCES

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A prospective epidemiologic study was carried out for 12 weeks in the winter of 1983 to evaluate the impact of indoor air contaminant levels on respiratory health. A group of 121 children below the age of 13 (59 with unvented kerosene space heaters in the home; 62 without) were enrolled in the study and nitrogen dioxide levels were measured in 93% of the subjects' homes for one two-week period. When socioeconomic status and history of respiratory illness were controlled, children under the age of seven exposed to 30 $\mu g/m^3$ or more of nitrogen dioxide were found to have a risk of reporting lower respiratory symptoms 2.25 times (95% C.I. 1.69-4.79) that of children who were not exposed. Aspects of our study design, including increased precision of exposure classification and the inclusion of very young children, may explain our findings.

INTRODUCTION

Conflicting evidence exists for a relationship between low levels of nitrogen dioxide, such as those that commonly occur in homes with unvented combustion sources, and adverse health effects, such as increased respiratory illness (Keller et al. 1979; Lebowitz et al. 1983; Melia et al. 1977, 1979, 1982; Speizer et al. 1980; Ware et al. 1984). Much of the research has been constrained to measure exposure by proxy—the presence or absence of a source, usually a gas cooking stove. While obtaining environmental measurements of exposure has been difficult due to expense and the greater level of cooperation entailed by respondents, the assumption has not been justified that the presence or absence of an unvented gas appliance is sufficient to categorize the exposure of a population. Nitrogen dioxide (NO_2) levels in homes using electricity for cooking have been measured at levels as high as 33.8 $\mu g/m^3$ (Goldstein et al. 1979). A number of factors, such as ventilation rate and the presence of other unnoted unvented combustion appliances, are frequently difficult to measure and can cause this wide range in exposure levels.

To assess the existence and the magnitude of an association between NO_2 levels and adverse respiratory outcomes, we wanted to capitalize on the increased use of kerosene heaters and their potentially high NO_2 emissions. Because NO_2 has been hypothesized to interfere with host defense mechanisms, lower respiratory illness, represented by symptom reports, was used to examine the association between

NO_2 and adverse health outcomes. Since acute respiratory infections are frequent, particularly among young children, greater power to detect differences in illness rates could be obtained from observing a relatively small number of subjects. In addition, reports in the literature indicated that young children would be most likely to be sensitive to any adverse effects from NO_2.

METHODS

Study design

A prospective cohort study of adult women and children was conducted from January to April 1983 in New Haven, CT, to delineate associations between low levels of indoor air contaminant levels (including NO_2, sulphur dioxide, and formaldehyde) and respiratory symptoms. A group of 121 children under the age of 13 was enrolled in this study, 59 living in homes with kerosene space heaters and 62 living in homes without heaters. To study the association between low levels of NO_2 and respiratory symptoms, we systematically chose one child from each family under the age of 13 and closest in age to 5. The participation rate was 78% of families living in homes with kerosene heaters, and 81% of those living in homes without heaters. The air monitoring design is described elsewhere (Leaderer et al. 1986).

Data collection

Data were gathered from several sources: baseline in-person interviews, 6 follow-up telephone interviews, measurements from passive monitors placed in 93% of the homes, and town tax assessor record abstracts.

The baseline interviews were administered between October 1, 1982, and January 14, 1983, and gathered information on demographics, medical history, building characteristics, and homeowner's heating patterns.

Follow-up telephone interviews were administered bi-weekly from January 30, 1983, to April 2, 1983. These consisted of: (1) a symptom checklist covering 20 symptoms of upper respiratory illness, lower respiratory illness, symptoms of general malaise, and a count of the number of days with each symptom, and (2) current heating patterns.

Data abstracted from town tax assessor records included the assessed value of the home, the materials used, the condition of the home, its age, the type of heating system and fuel used, the number of rooms and floors in the home, and the square footage of the bottom floor.

Approximately 93% of the children's homes were monitored with passive diffusion tubes for NO_2 for at least one two-week period. These tubes were placed in three locations inside the residence and one location outside. Sulphur dioxide, formaldehyde, and air infiltration rates were measured in a subsample of homes, but will not be reported here.

Definition of respiratory illness

The outcome variable of interest in this study was maternally reported acute respiratory illness, particularly lower respiratory illness. Lower respiratory symptoms included: fever, chest pain, productive cough, wheeze, chest cold, physician-diagnosed bronchitis, physician-diagnosed pneumonia, and asthma. Upper respiratory symptoms were also ascertained. They included: fever, sore throat, nasal congestion, dry cough, croup, and head cold. As the data were too sparse to analyze by individual symptom, clusters of lower respiratory symptoms and upper respiratory symptoms were formed, and incidence was summed for the entire study period of 12 weeks. A symptom cluster was considered present if two or more symptoms in the cluster were reported for one time period.

Definition of exposure

Accurate classification of subjects by exposure to NO_2 was a major priority of this project. During the study, exposure definition was improved beyond the anticipated dichotomy, so that children, who were initially identified as exposed or unexposed as a function of living in a home with a kerosene space heater or not, were classified according to measured NO_2 levels. Since measurements were taken for only one two-week period, NO_2 levels were estimated for all other periods based on hours of use multiplied by the level of NO_2 estimated during burning. These estimates were not significantly different from the measured NO_2 levels which were determined to be the least biased indicator of household exposure to NO_2 and thus were chosen as the most refined exposure variable.

Personal exposure estimates indicated a 94% correlation ($p < 0.01$) between monitors worn by a subsample of 23 adult subjects and the average estimate of the three monitored rooms in the household during the same time period. No higher correlation has appeared in the literature, and, in fact, Remijn (1985) reported that the household average NO_2 measurement is an excellent proxy for personal exposures.

Data analysis

Data were edited for consistency, coded, and quality control measures undertaken as the data were entered. Unconditional logistic regression analyses were performed to determine the magnitude and statistical significance of each factor controlling for all other variables in the model. With the exception of age, all the independent variables were continuous. Age was treated as dichotomous—younger than seven years and seven years and older. It should be emphasized that this type of analysis allows only a general comparison of variables and is highly dependent on the choice of cutpoint. Adjusted odds ratios were calculated using the LOGIST procedure of the Statistical Analysis System (Harrell 1983). Similar techniques were also used to assess effect modification and statistical interaction.

RESULTS

Demographic characteristics

Comparisons were made among the 113 monitored children as well as the 8 who were not monitored. They were very similar. The mean age of the children was 6.7 years, and 82% were away from home approximately 6 hours per day in school or daycare. The average household size was 4.2, the average socioeconomic status was moderate (Hollingshead 4-factor index)—42.5, and all children were Caucasian. There were approximately equal numbers of boys and girls in each group.

Measured household exposures to NO_2

Table 1 shows the measured NO_2 levels by each major category of NO_2 source: Kerosene Heater, Gas Stove, Gas Stove plus Kerosene Heater, and No Source.

Health effects; Lower respiratory symptoms

To assess the effect of NO_2 levels on the presence or absence of lower respiratory symptoms, while simultaneously controlling for effect modifiers and potential confounders, multiple logistic regression was carried out for the binary dependent variable, presence or absence of lower respiratory symptoms. Independent variables were included that had statistically significant relationships with respiratory symptoms in this study (SES, history of respiratory illness), and those which were cited in other studies as being important (household size, age, number of cigarettes smoked in the house per day, and exposure to NO_2).

Children under the age of 7 who were exposed to 30 $\mu g/m^3$ NO_2 had an odds for being reported as having lower respiratory symptoms 2.25 (95% C.I. 1.69-4.79) times those of unexposed children the

Table 1. Measured NO_2 values ($\mu g/m3$) in homes of monitored children (n=113) by source presence, Yale Health and Heating Study, New Haven, CT, area, winter 1983.

	Kerosene Heater + Gas Stove n=6	Kerosene Heater Only n=49	Gas Stove Only n=13	No Source n=4
Kitchen	89.50	41.07	40.92	6.40
Living Room	76.00	43.40	24.85	6.23
Bedroom	104.75	38.33	28.54	5.19
House Average	90.08	40.93	31.43	5.94

Table 2. Association between measured NO_2 levels and reported lower respiratory symptoms, by multiple logistic regression analysis, in 113 monitored children in the Yale Health and Heating study, New Haven, CT, area, winter 1983.

Variable	Odds ratio	95% CI
Age	1.05	0.91-1.21
SES**	2.35	1.14-4.85
History of Respiratory Illness	1.29	1.03-1.62
Age < 7 *30 $\mu g/m^3$ NO_2	2.25	1.69-4.79
Age =>7*30 $\mu g/m^3$ NO_2	0.84	0.59-1.42

*Hosmer goodness-of-fit: $x^2 = 6.41$, 6 d.f., p=0.38.
**20 units on the Hollingshead scale.

same age when the effects of a history of respiratory illness and SES were controlled (Table 2).

NO_2 exposure appeared to have no effect on reported lower respiratory symptoms in children aged seven or older. A history of respiratory illness and socioeconomic status contributed significantly and independently to the risk for reported lower respiratory symptoms. Children of higher socioeconomic status (20 units on the Hollingshead scale) were 2.4 times as likely as children of lower SES to be reported as having lower respiratory symptoms. A history of respiratory illnesses made the odds of reporting lower respiratory symptoms 1.3 times as likely in all the children. Exposure to environmental tobacco smoke was not significantly associated with reported symptoms in either age group.

DISCUSSION

In this study the ability to measure acute effects at the same time as exposure seems to have allowed for more precise estimates of the associated health effects—in terms of lower respiratory symptoms, the range of the susceptible group (less than seven years old), and other potentially important risk factors. Since the previous literature has shown inconsistent results, it seems that the effect of NO_2 is likely to be limited in many regards. It is plausible that there is a real biological effect, based on animal data and the trend toward seeing an effect in younger ages. Many studies have reported that SES plays a significant role as does a history of previous respiratory illness (see e.g., Monto and Ullman 1974).

A major strength of this study was that misclassification of exposure was limited, though not entirely, by the individual household measurement of NO_2 levels during one two-week period. If this study used dichotomous source classification (i.e., presence or absence of an unvented combustion source), as most research has been constrained to do, the association between lower respiratory symptoms and exposure would have been only marginally significant (p=0.08). Thus, the qualitative nature of previous data may have obscured the ability to define association between NO_2 and respiratory effects.

A limitation to the findings from this study is the currently unknown bias inherent in maternal reports of symptoms. However, we found no association between a mother's initial report of her child's propensity to illness assessed at baseline and subsequent reports of symptoms throughout the study.

CONCLUSION

The study has demonstrated a statistically significant association between NO_2 concentrations and the incidence of two or more lower respiratory symptoms in children under seven years of age. No such association was seen in older children. A history of previous respiratory illness and socioeconomic status

were significantly and independently associated with reported illness. This research has important implications for the present and possibly future health of young children exposed to NO_2 from any unvented combustion. The conclusions, however, are limited to this population and must be replicated, possibly with a population exposed to higher levels of NO_2, before they can be relied on as a basis for further action.

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